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NATIONAL DEFENSE RESEARCH COMMITTEE

REPORT NO. A-27 : PROGRESS REPORT

OSRD #311

ROCKET TARGETS

As of November 1, 1941

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by

A. J. Dempster

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NATIONAL DEFENSE RESEARCH COMMITTEE

REPORT NO. A-27 : PROGRESS REPORT

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ROCKET TARGETS

As of November 1, 1941

by

A. J. Dempster

Approved December 20, 1941
for submission to the Section Chairman

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Vice Chairman,
Section H, Division A

Approved December 22, 1941
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Approved December 23, 1941
for submission to the Committee

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Richard C. Tolman,
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Preface

The work described in this progress report is pertinent to the project designated by the War Department Liaison Officer as OD-26.

This development was initiated by a letter from J.B. Conant to E.C. Watson, dated August 15, 1941, enclosing a letter from Major General J.A. Green, Chief of Coast Artillery, to Brigadier General G.M. Barnes, War Department Liaison Officer to the National Defense Research Committee, on the subject, "Rocket Target for Automatic Weapons," and a memorandum from Lieutenant Colonel H.W. Dix to Doctor Bush.

At meetings of Section H on August 19 and August 29, 1941, it was agreed that the development of a target rocket should be undertaken by the NDRC. The particular work described in this report was carried out jointly by Sections H and E, Division A.

Distribution of copies of this report. -- The report was prepared for duplication on December 24, 1941. The initial distribution of copies was as follows:

Copies No. 1 to 23, inclusive, to the Office of the Secretary of the Committee for distribution in the usual manner;

Copies No. 24 and 25 to the Chief of the Bureau of Ordnance, U.S.Navy (Attention: Research and Development Division);

Copies No. 26 and 27 to the U.S. Naval Powder Factory, Indian Head, Md. (Attention: Lt. Comdr. H.J. Orth);

Copy No. 28 to Maj. L.A. Skinner, Ordnance Department, U. S. Army;

Copy No. 29 to C.N. Hickman, Chairman, Section H;

Copy No. 30 to A.J. Dempster, Vice Chairman, Section H;

Copy No. 31 to R.E. Gibson, Vice Chairman, Section H;

Copy No. 32 to A. Ellett, Chairman, Section E;

Copy No. 33 to E. C, Watson, Member, Section H;

Copy No. 34 to the Chief of Coast Artillery, U.S.Army (Attention: Major C.B.R. Schuyler)

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ROCKET TARGETS

As of November 1, 1941

1. Introduction

Rockets as targets for antiaircraft training have several advantages over the ordinary towed flags and sleeves. The speed may be made 200 to 250 mi/hr, as compared to 100 to 140 mi/hr with the sleeve. Also, the second half of the trajectory gives practice against a target that approaches the ground in a manner similar to a dive bomber. On the other hand, the rocket does not record successful hits, as does a flag, and it does not have the same visibility. The first disadvantage can be partially overcome by the use of tracer bullets, and the visibility can be improved to the point where the rocket is plainly visible to gunners.

Discussions with General Green, Chief of the Coast Artillery, led to the conclusion that a rocket would be very desirable as a target for training purposes if it had a velocity of 250-300 mi/hr, reached an elevation of 200-400 yd and were visible at a firing range of 500-2500 yd. In training, several firing stations might be used to secure variety in direction and trajectory; a whole battery would be on the alert and would endeavor to aim, but only one or two guns would receive orders to fire at any particular target. Results would be judged with the help of tracer bullets.

2. Preliminary rocket tests

Many observations on the flight of rockets had been made by Section E, Division A, the rockets used for this purpose having been developed at the National Bureau of Standards by Section E in connection with its work on fuzes. This rocket was about 4 ft long and 3-1/4 in. in diameter, and had four small fins, 2 × 8 in., welded to the rear of the main tube. It weighed about 17 lb and was propelled by approximately 450 gm of ballistite. As shown by tests at Aberdeen, Maryland, on August 13, 1941, the initial velocity v_o of a rocket of this type was about 260 mi/hr, and, when the rocket was projected at an angle ϕ of 45°, the range x was 1500 yd and the time of flight t about 17 sec. The highest point reached was about 375 yd, the velocity here having its minimum value, v_s, of 185 mi/hr. Thus the speed of a rocket of this type was only slightly smaller than that desired for rockets used as targets. However, the rocket was lacking in visibility. It was difficult to locate in flight unless followed from the beginning. As observed from a place 200 yd from the firing point, it could be kept in view during the whole flight but, once lost, was difficult to pick up again.

To increase the visibility two methods were tried: (a) large vanes or tails were attached to the rocket to enlarge the surface, and (b) a smoke pot was used to keep the eye attracted to the rocket.

(a) Two rockets with large tails were made by Section E at the National Bureau of Standards and were tested at Aberdeen, Maryland, on August 31. On one of these rockets four tails were fastened, each 1 × 2 ft. This rocket was 6 ft long, weighed 50 lb and had a propellant charge of 800 gm. The motor did not behave properly, much of the powder was expelled and the flight was short, lasting only 9 sec. The other rocket was equipped with four semicircular tails of diameter 20 in., weighed 20 lb and had a propellant charge of 800 gm. Again the flight was short, lasting only 11.4 sec, this being due to incomplete burning of the powder. In both cases the velocities were much below those aimed at, probably only 120-170 mi/hr. The tests showed that the fins added a great deal to the visibility; the rockets were plainly visible throughout the flight.

(b) The use of smoke to increase visibility was tested on September 19 at Indian Head, Maryland, on two rockets that weighed approximately 20 lb each. These were equipped with smoke pots[1/] designed to burn 20-25 sec. The smoke pot was ignited by means of a squib with a separate firing circuit, about 2 sec before the rocket was fired. Approximately 800 gm of propellant was used, and the rockets were projected at 60° with the horizontal. Times of flight of 28 and 40 sec were observed. The initial velocities were more than sufficient, and it was found

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1/ Made by Triumph Explosives, Inc., Elkton, Md. (Navy Drawing 164964).

that the smoke tail made it very easy to keep the target in view. Smoke pots have been used regularly in tests of photo-electric fuzes and have been found useful in locating the trajectory of the rocket.

3. Tests of five rocket targets at Aberdeen, September 29, 1941

Five rockets were tested at Aberdeen on September 29, 1941.[2/] The rockets were fitted with four semicircular fins, 20 in. in diameter, that had been constructed at the National Bureau of Standards on the design of Dr. C. C. Lauritsen and proved to be sufficiently rigid. Each fin was made of two pieces of sheet metal separated and strengthened by wooden supports inside. They were fastened by bolts to four 8 x-2 in. vanes welded to the motors.

Table I gives the sizes, weights and amounts of propellant used, and the observed times of flight at 45°. The last two lines

Table I. Tests of September 29, 1941.

Target	1	2	3	4	5
Weight (lbs)	24.5	23.75	25.1	30.25	28.5
Length (ft)	5	5	5	6-1/3	6-1/3
Diameter (in.)	3-1/4	3-1/4	3-1/4	3-1/4	3-1/4
Powder (gm)	451	452	453	867	870
Time, 45°(sec)	11.4	12.1	12.3	15.8	18.0
v_o, approx. (mi/hr)	177	185	190	245	280
v_s, approx. (mi/hr)	125	132	135	172	195

of Table I give approximate values of the initial velocity v_o and the velocity at the highest point of the trajectory v_s, as

2/ These tests were observed gy General Green, Major Bartlett, Major Skinner and other officers of the Aberdeen staff. Members of the NDRC who were present included Doctor Ellett, who was in charge of the firing, and Doctors Becker, Dempster, C.C.Lauritsen, T. Lauritsen, Streib and Taylor.

computed from the time of flight on the assumption of negligible air resistance. The actual values, in the light of later tests, were probably higher for v_o and very much lower for v_s.

As a result of these tests it was agreed that the last two rockets were more satisfactory than the first three and that the velocities acquired with them would be useful for training anti-aircraft gunners.

Later on the same day five 30-lb targets were fired with 1200 gm of propellant. The flights of three of these rockets were good. Only approximate values of the time of flight and angle of projection were obtained, but these indicated that the initial velocity was about 380 mi/hr.

4. Tests of 11 rockets at Fort Monroe, Virginia, October 11, 1941

Eleven rockets with semi-circular tails about 20 in. in diameter, similar to those used at Aberdeen on September 29 (Sec. 3), were fired at an angle of projection of 45°, approximately 1140 gm of powder being used. Six good flights lasting about 21 sec and having a range of about 1900 yd were obtained. Four of the flights were shorter, being 16.6-18.2 sec. In one case the chamber exploded, resulting in a flight of only 12.6 sec.

The range obtained was decidedly less than that computed from the time of flight on the assumption of negligible air resistance. Thus 1920 yd was obtained in place of a computed value of 2350 yd. In this range of velocities the air resistance is closely proportional to the square of the velocity, and

the velocities may be computed from the range and time of flight by means of the Didion-Bernoulli approximation method. For the six good flights of approximately 21 sec duration and 1920 yd range, this method yields the following approximate values:

Initial velocity, v_o, 450 mi/hr;

Velocity at top of trajectory, v_s, 170 mi/hr;

Velocity at end of trajectory, 240 mi/hr;

Angle of projection, ϕ, 45°;

Angle at end of trajectory, ϕ', 63°.

The targets were fired at with 0.50-caliber machine guns and 37-mm antiaircraft guns, tracer bullets being used to indicate the accuracy of the fire.3/ Predictor apparatus was also tried.

The general opinion was that the rockets as tested would be very useful for target practice. The velocities obtained were higher than those that are possible with towed targets. The trajectory varied in direction, and the second half of the trajectory simulated a dive bomber. It was decided to have a considerable number of targets of the present model made.

Six of the rockets were fitted with smoke pots which were ignited by a separate firing circuit a second or two before the rocket was fired. These left a narrow trail of smoke behind the rocket that could be readily seen and that guided the eye to the black rocket at the end of the smoke trail.

3/ These tests were observed by General Green, Major Bartlett, Major Skinner and many Coast Guard officers and personnel. Doctors Ellett and T. Lauritsen were in charge of the firing. Also present were Doctors Tolman, C.C. Lauritsen and Dempster.

In a conference with Major Bartlett, the Commanding Officer and Doctor Dempster, the four machine gunners stated that the smoke was of help in keeping on the target; the field of view of the sight-telescope was so small that they were liable to lose the target, in which case it was necessary to look outside the sight, find the target and train the sight on it again. The smoke aided materially in finding the target again rapidly. In these tests the rockets were projected from the south to the north and passed in front of the sun before coming within range. This made it particularly difficult to follow the rocket throughout the whole trajectory and often made it necessary to pick up the target again after it had passed the sun. To observers other than the gunners the rockets appeared easily visibile, so that smoke pots seemed unnecessary.

5. Test of 18 rockets at Fort Monroe, October 30, 1941

Eighteen rockets constructed by Section E at the National Bureau of Standards were tested at Fort Monroe on October 30, 1941.[4/] Six were provided with four large circular tails of diameter 20 in., similar to those used previously (Sec. 4). A second group of six rockets were equipped with yellow smoke pots and various types of whistles; on two, British bomb whistles were attached to the fins. These first twelve rockets had 1150-1200 gm of propellant each. The remaining six rockets

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4/ The tests were observed by General Green, Major Bartlett and other officers of the Coast Artillery. The projection was in charge of Doctors Ellett, Taylor and McLain. Doctors Becker and Dempster were also present.

were small, weighing approximately 20 lb and having only 450 gm of powder; they had no large tails but were equipped with smoke pots to increase their visibility.

A new projector was used which was provided with electric contacts. These contacts made electric connections with three contacts on an insulating ring that fitted over the nozzle of the rocket. The cable from the firing box was connected permanently to the projector. The three connections were used to fire, first the smoke pot and, a few seconds later, the main charge.

The angles $\underline{\phi}$ with the horizontal, the times of flight $\underline{t}$ and the ranges $\underline{x}$ as reported by the Coast Artillery observers are listed in Table II. The first group of six rockets are the

Table II. Tests of October 30, 1941.

Round	Angle $\underline{\phi}$ (deg)	Time of Flight $\underline{t}$ (sec)	Range $\underline{x}$ (yd)	Max. Height (yd)
1	45	22.9	1900	
2	45	22.3	1950	
3	55	23.0	1600(est.)	
4	55	24.7	1790	790
5	40	20.1	1897	
6	35	18.4	1910	555
7	35	17.2	1900(est.)	
8	35	17.1	1575	
9	35	16.2	1475	
10	35	17.5	1850	
11	35	15.8	1875	300
18	45	22.0	1900(est.)	
12	35	11.7	1100(est.)	
13	35	12.1	1000	
14	45	15.8	1100(est.)	
15	45	14.9	1100	
16	45	15.5	1100(est.)	
17	45	14.7	1110	

large ones with four semicircular tails. The second group are the similar rockets fitted with smoke pots and various whistles. The third group are the small rockets without tails but with smoke pots.

There were no bursts of the motors. The powder had been carefully inspected at Indian Head two days before the test, and 20 to 25 percent of the pieces had been rejected on account of holes.

The targets were projected from a station on the beach about 1200 yd north of the firing point and in a direction bearing about 30° out from the shore line. Thus they were fired on toward the end of their range. The last six targets listed in Table II fell short of the firing point and hence were not satisfactory as targets. The projection point was so far away that these last six rockets could not be picked up with certainty at the beginning of the flight and it was difficult to pick them up later. In the case of small targets it would be advisable to move the point of projection up to 200 yd from the firing point, so that the gunners could get their eye on the rocket early in the trajectory. In these tests the smoke pots were not of as much aid as they were in the tests of October 11. This was probably due to the fact that the smoke pots used were yellow, instead of black or green, which give a denser trail, and also to the fact that the point of projection was so far from the firing point that the smoke was usually exhausted before the target passed the firing point.

In the opinion of most observers, the whistles used on the six rockets of the second group did not aid in locating the rockets. Owing to the high velocities, the sound and the rocket appeared to come from different directions. Moreover, the sound was not loud enough to give the psychological effect reported for whistles on bombs. The production of the noises accompanying an airplane attack can be achieved directly at the firing point by other methods.

The first twelve targets were large enough to be easily seen from the firing point, from the very beginning of their flight. There was no trouble with the sun, as was the case in the tests of October 11. General Green was of the opinion that the first twelve targets were eminently satisfactory for training purposes.

6. Velocities of the targets

The ranges of the last six targets listed in Table II agree with that calculated from the time of flight t on the assumption of negligible air resistance, thus indicating that the air resistance was of minor importance. The velocities, neglecting air resistance, are approximately: v_o and v_f, the initial and final velocities, 230 mi/hr; v_s, the velocity at the top of the trajectory, 165 mi/hr in the case of 45° projection and 190 mi/hr in the case of 35° projection.

Until direct measurements of the initial velocity have been made, it is possible to give only approximate values of the

velocities actually obtained in the case of the first twelve targets. The ranges are decidedly less than those computed from the time of flight on the assumption of negligible air resistance. If it is assumed that the air resistance is proportional to the square of the velocity, the velocities and trajectories may be computed from the two observed data -- range x and time of flight t -- by means of the Didion-Bernoulli approximation method. The results of this computation for some of the rounds are given in Table III.

Table III. Computation of initial velocity v_o, the summit velocity v_s, the final velocity v_f and the angle ϕ' at the end of the trajectory from the data of Table II.

Round	ϕ (deg)	t (sec)	x (yd)	v_o (mi/hr)	v_s (mi/hr)	v_f (mi/hr)	ϕ' (deg)
2	45°	22.3	1950	460	170	234	62.7
4	55	24.7	1790	395	145	265	67.3
5	40	20.1	1897	444	185	230	58.7
6	35	18.4	1910	455	205	224	53.6
8	35	17.1	1575	445	160	186	56.4
9	35	16.2	1475	400	177	195	54.0
10	35	17.5	1850	395	216	230	49.0
18	45	22.0	1900	444	170	243	63.1